DUPONT PERSONAL PROTECTION

TECHNICAL BULLETIN
NUCLEAR RISKS

PROTECTION FROM RADIOACTIVE CONTAMINATED PARTICLES OR LIQUID HAZARDS

Protection from nuclear hazards can be divided into two main areas: protection against ionizing radiation hazards and protection against radioactive particle or liquid hazards.

The fabrics used in single-use protective garments do not provide a barrier to **ionizing radiation** (e.g., gamma rays, X-rays or radioactive alpha or beta particles). The standard protocol used to reduce radiation exposure would include time, distance and shielding. For garments, limited shielding may be provided by specialty garments that contain lead-based materials. DuPont does not offer any specialty garments that provide protection from **ionizing radiation** hazards.

For hazards associated with **radioactive contaminated** particles or liquids, rather than blocking the radiation itself, appropriate garments are designed to minimize the penetration of radioactive materials, thereby also keeping contact with the skin and clothing worn underneath to a minimum. These garments are designed to be worn in a potentially affected area and then be promptly removed and disposed of, such that long-term exposure to the radioactive contaminated material is minimized after leaving the potentially affected area and to avoid contaminating other areas.

EN 1073-1 and EN 1073-2

Chemical protective garments are intended for single use so that a cross-contamination with radioactive particles can be minimized.

DuPont offers specially designed garments that help provide protection from radioactive particles and liquids. Specific fabric types, seam configurations and garment designs should be specified to match the hazard.

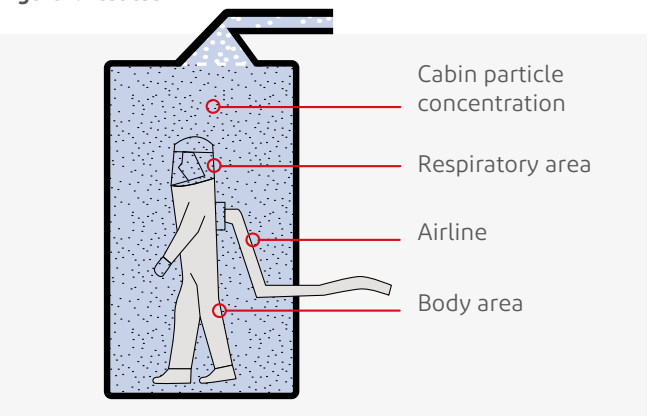
In general, more body coverage is better:
Hooded coveralls (with attached socks) or fully encapsulated coveralls help to protect the entire body from radioactive particulates.

DuPont™ Tyvek® 500 Xpert, Tyvek® 600 Plus, Tyvek® 800 J, Tychem® 2000 C Standard, as well as Tychem® 6000 F Standard garments & Tychem® 6000 AL are tested according to **EN 1073-1 or EN 1073-2** as protective clothing against radioactive contamination. EN 1073-1 standard is designed for compressed air line ventilated protective clothing, protecting the body and the respiratory tract, and EN 1073-2 for non-ventilated protective clothing against particulate radioactive contamination.

EN 1073-1: requirements & test methods for compressed air line ventilated protective clothing, protecting the body & the respiratory tract

The tests are run in a cabin containing very fine salt particles with an operator wearing a ventilated protective clothing while doing a series of movements. The particles measured inside the coverall (both in the respiratory area and in body) will be compared with the particle concentration within the cabin (outside of the coverall) to assess the nominal protection factor (NPF).

Figure 1: Test cabin



Nominal protection factor according to EN 1073-1:

Calculate the percentage total inward leakage (T.I.L) for each exercice as follow:

$$T.I.L = \frac{C_1}{C_2} x100(\%)$$

Where

C_1 = mean concentration at the sampling point for each exercice;

C_2 = concentration in enclosure.

The test results shall be reported according to the following tables:

Table 1 - TIL test results for the respiratory area

Respiratory area	Test subject 1	Test subject 1	Test subject 2	Test suject subject 2
—	j=2 sample 1	j=2 sample 2	j=3 sample 3	j=4 sample 4
i = 1 Standing still	$TIL_R(1,1)$	$TIL_R(1,2)$	$TIL_R(1,3)$	$TIL_R(1,4)$
i = 2 Walking 5 km/h	$TIL_R(2,1)$	$TIL_R(2,2)$	$TIL_R(2,3)$	$TIL_R(2,4)$
i = 3 Moving arms	$TIL_R(3,1)$	$TIL_R(3,2)$	$TIL_R(3,3)$	$TIL_R(3,4)$
i = 4 Squatting	$TIL_R(4,1)$	$TIL_R(4,2)$	$TIL_R(4,3)$	$TIL_R(4,4)$
Mean values for all the activities	$M_R(1)$	$M_R(2)$	$M_R(3)$	$M_R(4)$

TIL_R: Total Inward Leakage in the respiratory area.
M_R: Mean values for all the activities in the respiratory area.

Table 2 - TIL test results for the body

Body	Test subject 1	Test subject 1	Test subject 2	Test suject subject 2
	j=2 sample 1	j=2 sample 2	j=3 sample 3	j=4 sample 4
i = 1 Standing still	$TIL_B(i,j)$	$TIL_B(i,j)$	$TIL_B(i,j)$	$TIL_B(i,j)$
i = 2 Walking 5 km/h	$TIL_B(i,j)$	$TIL_B(i,j)$	$TIL_B(i,j)$	$TIL_B(i,j)$
i = 3 Moving arms	$TIL_B(i,j)$	$TIL_B(i,j)$	$TIL_B(i,j)$	$TIL_B(i,j)$
i = 4 Squatting	$TIL_B(i,j)$	$TIL_B(i,j)$	$TIL_B(i,j)$	$TIL_B(i,j)$
Mean values for all the activities	$M_B(1)$	$M_B(2)$	$M_B(3)$	$M_B(4)$

TIL_B : Total Inward Leakage in the body excluding the respiratory area.
M_B : Mean values for all the activities in the body excluding the respiratory area.

Inward leakage test results (TIL_R, TIL_B, M_R, M_B) for ventilated protective clothing shall be classified according to Table 2. For the complete suit, the lowest class obtained defines the final test result, and the corresponding nominal protection factor. This classification shall be at least class 1.

Table 3 - Leakage - Classification (EN 1073-1)

	Maximum values for one activity (%)	Maximum values for all the activities (%)	Minimal nominal protection factor
Data that shall be classified	TIL_R TIL_B	M_R M_B	Nominal protection factor*
Class 5	0,004	0,002	50 000
Class 4	0,01	0,005	20 000
Class 3	0,02	0,01	10 000
Class 2	0,04	0,02	5 000
Class 1	0,10	0,05	2 000

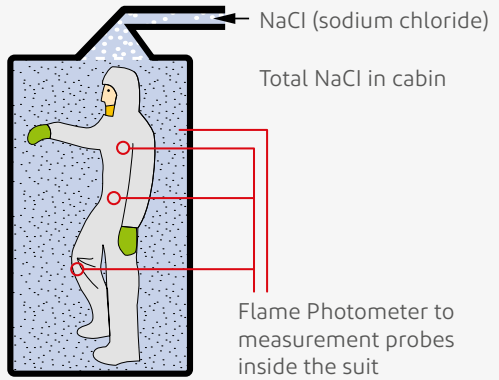
NOTE: Nominal protection factor (NPF) is the reciprocal of the inward leakage obtained during all the activities (M_R or M_B). Its calculation is then given by the following relation: NPF=100: $M_{R/B}$,when $M_{R/B}$ is the maximum value from M_R or M_B expressed in %.

EN 1073-2: requirements & test methods for non-ventilated protective clothing against particulate radioactive contamination

The EN 1073-2 standard was developed with the nuclear industry in mind, but does not apply for the protection against ionizing radiation. The 1073-2 standard itself is very similar to the Chemical Protective Clothing Type 5 standard (EN ISO 13982-1).

With respect to whole suit particle protection levels, both standards reference the testing protocol "Protective clothing for use against solid particulates - test method of determination of inward leakage of aerosols of fine particles into suits" (EN ISO 13982-2). This test essentially determines the barrier efficiency of the suit when challenged with sodium chloride particulates of a defined size distribution. The results are then used to determine both a **performance classification** and a "**nominal protection factor**", analogous to respiratory standards.

Figure 2: The suit inward leakage test



For EN 1073-2, when tested according to EN 13982-2, six suits are tested. The total inward leakage results (TIL) are reported, as a ratio (in %) of the test particle concentration inside the suit & the test chamber:

$$\text{Total Inward Leakage (TIL)} = \frac{\text{Concentration of test particules (inside suit)}}{\text{Concentration of test particules in the chamber}}$$

Nominal protection factor & performance class (EN 1073-2 / EN 13982-2)

There are three types of performance class to describe the suit particle protection level:

Class 1 = Lowest particle barrier | Class 3 = Highest particle barrier

$$\text{Nominal Protection Factor} = \frac{100}{\text{Total Average Inward Leakage}}$$

In other words, a suit which offers the **highest protection** to the fine particulates will have **LOW inward leakage**, and thus a **HIGH nominal protection factor**.

A suit which offers a low nominal protection factor, e.g. "5", means it has an average of 20% inward leakage.

To determine the performance classification, the total average inward leakage value per activity (standing, walking and squatting) is calculated (TILE). This value and also the Nominal protection factor are both considered in order to determine which performance class is attributed to the suit. **See Table 4.**

Table 4 - Leakage - Classification (EN 1073-2)

	Mean value of inward leakage at the three sampling positions inside te suit during exercise		
Class	One activity (TILE) %	All activities (TILA) %	Nominal protection factor*
3	0.3	0.2	500
2	3	2	50
1	30	20	5

** Nominal protection factor = 100 / TILA.*

A performance class of 3, i.e. the "highest" performance class can be understood as: The highest value for the inward leakage measured for each of the three activities (TILE) is less than 0.3% and also the overall total average inward leakage (TILA) is less than 0.2 %.

Dry Environment Contamination of Radioactive Particles

For dry radioactive particle hazards, **hooded DuPont™ Tyvek® coveralls** are suggested for your consideration. In addition, whether or not over-taped seams are required would be dictated by the expected intensity of the exposure. Garments with over-taped seams offer a higher overall protection to particles than garments with stitched seams and should ideally be preferred.

Mixed Dry & Wet Environments, Contamination of Radioactive Particles and Liquids

For liquids that have been contaminated by radiation, hooded Tychem® 2000 C & 6000 F coveralls may provide protection of the wearer from the chemical hazard, but not from ionizing radiation.

Based on the chemical permeation data, you are able to select the fabric that offers an adequate chemical barrier. In order to access the permeation data for the DuPont™ SafeSPEC™ fabrics you may visit DuPont™ SafeSPEC™ or contact us.

Table below shows the performance of some of the different DuPont garments in terms of Nominal Protection Factor and the corresponding performance class (according to EN 1073-1 or EN 1073-2) and below indicates the preferred and adequate solutions in case of mixed particulate and liquid contamination. Nevertheless, depending on the risk assessment of the application different solutions might be required. Contact us for technical support in appropriate garment selection.

	DuPont garment name	Fabric description	Seam type	Certification types	NPF*	Class	Nuclear Hazards - Descriptions & examples			
							Dry contamination	Mixed dry & wet contamination		
							Radioactive particles	Radioactive particles, liquid mist & aerosols	Radioactive particles & heavy liquid spray with concentra ted inorganic chemicals**	Radioactive particles & heavy liquid spray with a range of organic chemicals**
	**Tychem® 6000 AL** (different model options available)	Tychem® 6000	Stitched & over-taped	3-B, 4-B, 5-B & 6-B	50000	5/5	○	○	○	●
	**Tychem® 6000 F & 4000 S** (different model options available)	Tychem® 6000 & 4000	Stitched & over-taped	3-B, 4-B, 5-B & 6-B	5***	1/3***	○	○	○	●
	**Tychem® 2000 C** (different model options available)	Tychem® 2000	Stitched & over-taped	3-B, 4-B, 5-B & 6-B	5***	1/3***	○	●	●	●
	**Tyvek® 800 J**	Tyvek® 800	Stitched & over-taped	3-B, 4-B, 5-B & 6-B	50	2/3	●	●	●	●
	**Tyvek® 600 Plus** (with attached socks)	Tyvek® 600	Stitched & over-taped	4-B, 5-B & 6-B	50	2/3	●	●	●	●
	**Tyvek® 500 Xpert**	Tyvek® 500	Stitched	5-B & 6-B	50	2/3	○	○	●	●
	**Tyvek® 400 Dual TG**	Tyvek® Front SMS rear	Stitched	5 & 6	5	1/3	●	●	●	●
	**Tyvek® 400 Dual**	Tyvek® Front SMS rear	Stitched	5 & 6	5	1/3	●	●	●	●
	**ProShield® 60**	Microporous film	Stitched	5 & 6	5	1/3	●	●	●	●
	**ProShield® 20 & 20 SFR**	SMS	Stitched	5 & 6	5	1/3	●	●	●	●

Warning: The garments do not provide a barrier to ionizing radiation

*NPF=nominal protection factor **Verify chemical permeation data.

***Since Type 5 (EN ISO 13982-2) test is done with sodium chloride particles that are measured inside the coveralls, the results of inward leakage for non-breathable materials (such as Tychem®) are typically higher than for breathable materials (such as Tyvek®).

● Not recommended ○ Adequate ● Preferred ○ Potentially over-specified

In addition, other appropriate PPE, such as but not limited to respirators, goggles, gloves and footwear, etc., as identified during the hazard assessment, should be used in conjunction with any garment selection. Donning, doffing, and disposal of radioactive contaminated garments should only be conducted by properly trained personnel.

NOTE: Products that utilize 'SMS' or microporous film substrates (e.g., DuPont™ ProShield® 20 [SMS] and DuPont™ ProShield® 60 [microporous film]) are appropriate for particle protection, however careful consideration should be given to using products that utilize SMS or microporous film substrates for disaster response activities because:

1. Microporous film fabrics may be easily abraded and the barrier layer can be readily worn away. 2. "SMS" fabrics tend to have quite open structures, offering low dry particle holdout performance to fine particulates.

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Additional Resources
Case study with the United Kingdom Atomic Energy Authority (UKAEA)
DuPont Personal Protection, Nuclear Industry protection web page

DuPont™ SafeSPEC™

DuPont™ SafeSPEC™ - We're here to help

Our powerful web-based tool can assist you with finding the appropriate DuPont garment for chemical or cleanroom environment.

safespec.dupont.co.uk

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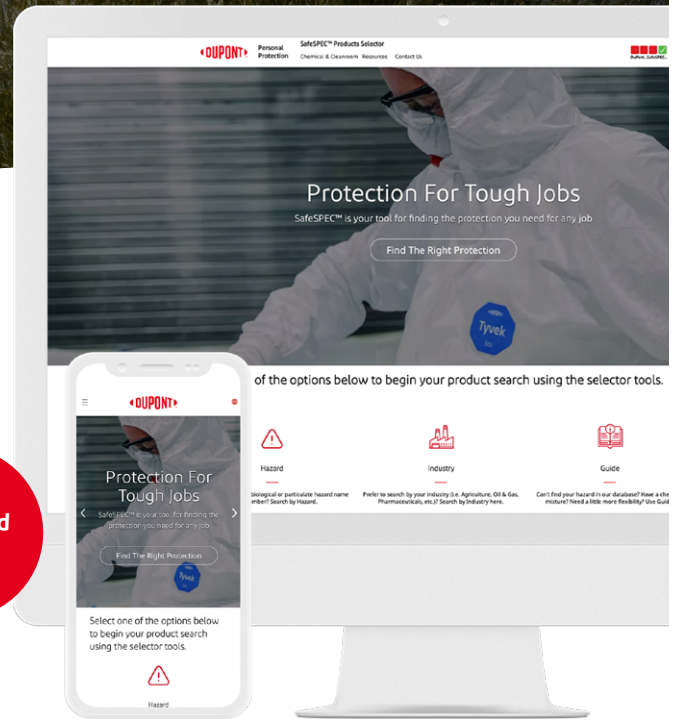

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tyvek.com/ppe

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